SOME EXPERIMENTS ON THE DISINFECTION OF ROOMS BY GASEOUS FORMALDEHYDE.

THE value of formic aldehyde (CH_2O) as a gaseous disinfectant has been fully established by the work of numerous observers both abroad and in this country. This gas may be produced by imperfect oxidation of methyl alcohol (CH_4O) or when vapours of this alcohol mixed with air are made to pass over certain hot metals such as copper, silver, platinum, or palladium. A more complete oxidation would ultimately give rise to carbon monoxide, carbon dioxide, or formic acid * and water, *e.g.*—

$$2\,CH_3OH + 3\,O_2 = 2\,CO_2 + 4\,H_2O;$$
$$CH_3OH + 2\,O = HCOOH + H_2O.$$

Several lamps have been devised in which methyl alcohol vapours are oxidised by being made to pass over finely-divided platinum (platinised asbestos is generally used). Some of these lamps are imperfect, either because a more or less considerable portion of the methyl alcohol is not acted upon, or else because the oxidation goes beyond the required degree, in both cases the quantity of formic aldehyde generated is much reduced and may be insufficient for the purposes of efficient disinfection.

Trillat, to whom we owe chiefly the introduction of formic aldehyde gas as a disinfectant, and who has himself devised a formogenic lamp, has finally adopted another method for the generation of formic aldehyde.

He heats under a pressure of several atmospheres a pure 30 to 40 per cent. watery solution of formic aldehyde to which 4 to 5 per cent. of a neutral chloride (chloride of calcium) have been added (formochlorol so called). Under these conditions almost pure and dry active formaldehyde gas may be obtained without any sensible loss being produced by polymerisation or escape of methyl alcohol. There can be no doubt as to the excellence of the results obtained by Trillat's method, but the autoclave necessary to generate the gas is expensive, it is somewhat heavy, and its working must be watched with some care.

Knowing that I was interested in the disinfection of rooms, Dr. Mills,

* The conditions under which methyl alcohol is oxidised in formogenic lamps are not favourable to the production of formic acid.

of Brussels, attracted my attention at the beginning of last year to the excellent results obtained with a lamp devised by Mr. F. Richard, of the same town. Being satisfied that anything which could make the process of disinfection by formaldehyde generally accessible, would prove of great use, I determined to try this form of generator.

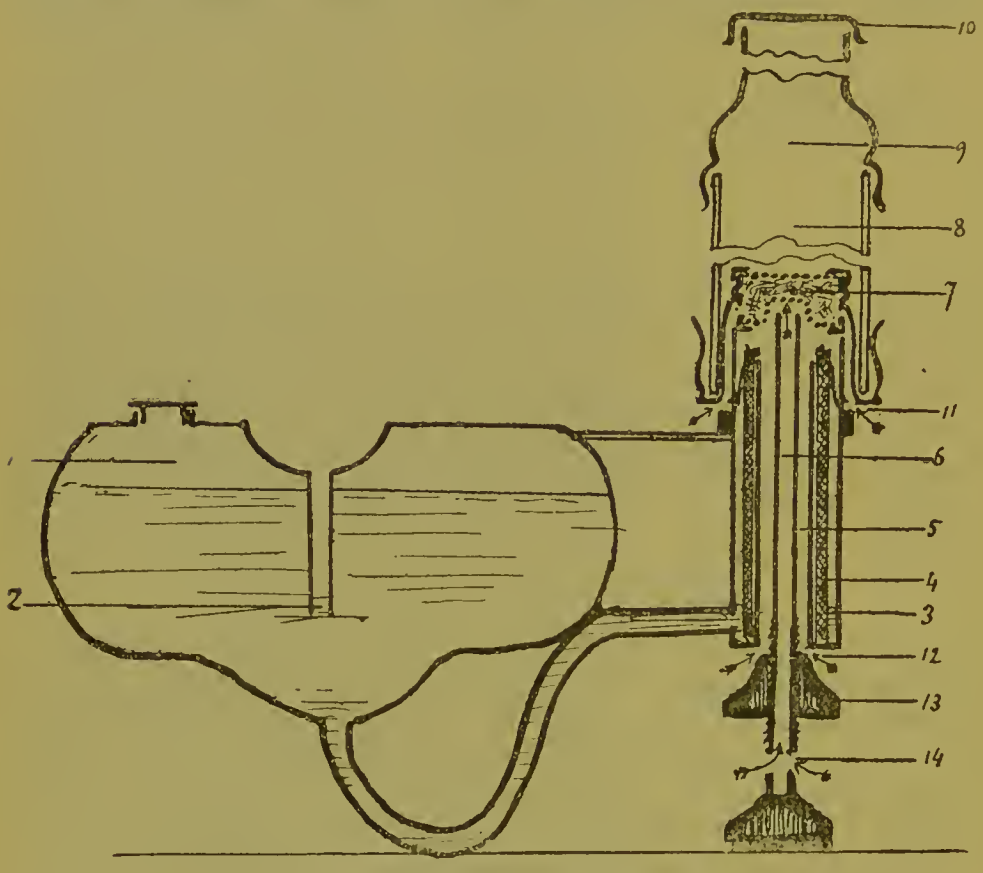

FIG. 1.—FORMOGÈNE RICHARD.

(*One burner only is represented.*)

1. Reservoir for methyl alcohol.
2. Mariotte's tube, regulating the level of the spirit in the wick-holder.
3. Wick-holder. 4. Wick.
5. Internal space admitting air to the wick when its lower opening (12) is opened.
6. Central tube admitting air to the central parts of the platinised asbestos case.
7. Platinised asbestos case or chamber (reaction chamber) composed of wire gauze, and with lateral openings to admit air coming through the openings (11).
8. Glass chimney (partly represented).
9. Metallic chimney (partly represented).
10. Cap used to extinguish the lamp completely.
11. Air-holes admitting air to the sides of the platinised asbestos chamber, but not to the wick.
12. Opening admitting air to the wick, and which can be closed by the obturator (13).
13. Obturator, which can be screwed up and down so as to close or open the aperture (12).
14. Openings admitting air to the tube (6).

Formogène Richard (fig. 1).—This lamp is composed of a reservoir for the methylic alcohol. From the bottom of the reservoir the methylic

alcohol is led to the burners by U-shaped tubes. The pressure under which the alcohol passes out of the reservoir is rendered constant by the action of a Mariotte's tube. The burner is cylindrical and resembles in construction an Argand's burner. This burner is, however, so arranged that it can be covered with a cap or brass bell, the upper part of which is formed by a wire case containing platinised asbestos.

So long as air is allowed to reach the wick from below, the spirit continues to burn with a flame even after the bell has been placed over it; but by closing the lower part of the tube, allowing air to pass to the wick, the flame is extinguished. If the flame is put out after the platinised asbestos has been heated sufficiently, the alcoholic vapours will continue to rise and, on coming in contact with the hot, finely-divided platinum, will become oxidised so as to form formic aldehyde and water. Air is supplied to all the parts of the wire case containing the platinised asbestos.

The heat liberated by the combination taking place on the platinum surface is sufficient to warm the metallic tube containing the wick and to cause evaporation of the wood spirit. This goes on until practically all the alcohol contained in the reservoir has been used up.

When methyl alcohol sufficiently pure and free from water is used in the lamp, it is, according to Monsieur Richard, entirely transformed into formic aldehyde. Certainly the amount of aldehyde produced is so considerable that a few minutes after lighting one of these lamps in a room of more than 1,500 cubic feet capacity I found it invariably impossible to remain in that room more than a few minutes, owing to the intense irritation of the mucous membranes of the eye and air passages produced by the formaldehyde generated.

The lamp I experimented with had three burners and a reservoir holding three litres (3,000 c.c.) of alcohol. It is claimed that such a lamp is capable of disinfecting a room of a capacity of about 100 cubic yards (*i.e.*, about 2,700 cubic feet).

I found no difficulty in following the directions given for its use. I lighted the lamp more than thirty times, and on each occasion the generation of formaldehyde took place rapidly and readily, and continued till practically the whole spirit placed in the reservoir had been oxidised. In the disinfection experiments the lamp was left for 24 hours in the closed room after being charged with 3,000 c.c. of methyl alcohol. At the end of the 24 hours not more than 40 or 50 c.c. of alcohol remained in the lamp.

Experimental Room (fig. 2).—The room I have set apart for disinfection experiments in my laboratory at the Owens College is an oblong room with only one external opening, viz., the door. The door fits well, so that the room can be closed more perfectly perhaps than

an ordinary living room would. With that exception, which must be allowed in order that experiments with various disinfectants should be strictly comparable, this disinfection chamber is like a living room of moderate size.

The floor measures 19 ft. 3 ins. by 7 ft. 10 ins.; the height is 11 feet. The walls are made of moderately porous bricks, white-washed. The floor is concreted and there is an ordinary plaster-of-paris ceiling. Owing to a brick casement occupying one angle of the room under the ceiling, the cubic capacity is slightly less than the above measurements would indicate, being reduced to 1,609 cubic feet.

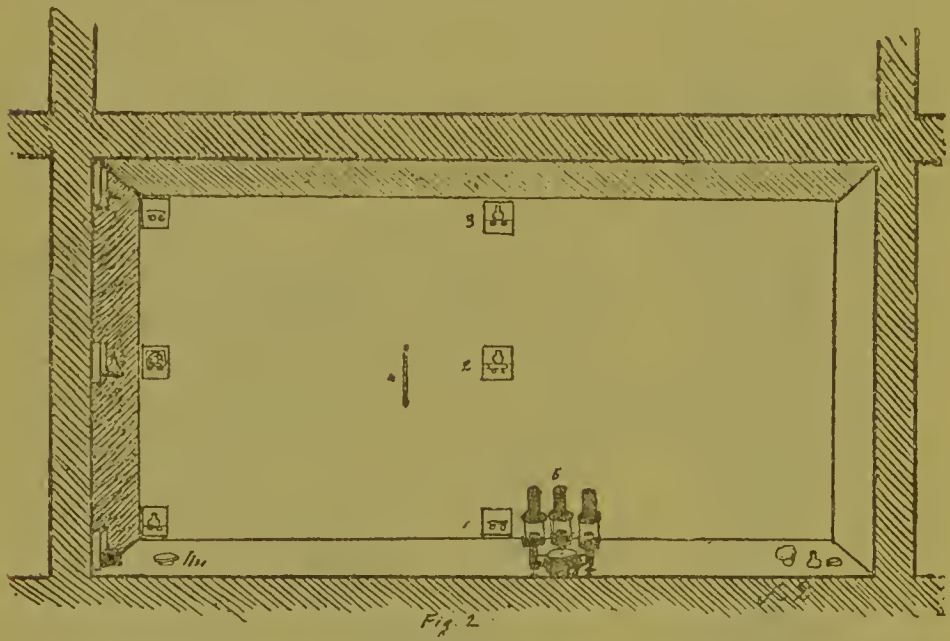

FIG. 2.—SECTION OF EXPERIMENTAL DISINFECTION CHAMBER.

The half opposite to the door is represented. The position of the lamp and of the various brackets are represented, but the lamp is drawn to a scale a little larger than that at which the other objects are drawn.

1. Bracket, 6 inches above the floor.
2. ,, 6 feet ,, ,,
3. ,, 10½ ,, ,, ,,
4. Thermometer.
5. Formogenic lamp (scale somewhat larger than that of the room).

The temperature of this room is, owing to the passage of hot-water pipes in the casement above mentioned, never below 19° C. During my experiments with formaldehyde it oscillated between 20° C. and 22° C.

The room is quite dry.

There are brackets situated in the middle of each wall and in the angles of the room. In each one of those situations one of the brackets is placed 6 inches, another 6 feet, and a third 10 ft. 6 ins. above the floor.

On these brackets are placed the tubes, dishes, &c., containing the tests, or small vertical wooden boards, to which the test objects may be fixed in various ways.

Test Objects.—I have found it convenient to reduce the number of micro-organisms used for the purpose of testing aerial disinfectants to a few which are capable of being dried for many days without sensibly losing their power of growth, either in artificial media or in living tissues. Some of these are sporing organisms, and have a high degree of resistance. Others are, so far as we know, non-sporing, and are readily killed. The tubercle bacillus in sputum is used to test at the same time the action of the disinfectant on the bacillus, and its penetrating power with regard to morbid discharges fresh or dry. I usually exclude from this list of test cultures those of the typhoid bacillus and of the vibrio of cholera, which do not stand drying well, and are readily killed by most disinfecting agents having any claim to efficiency. I think also that the bacillus of diphtheria is not a very suitable organism, either for cultivation or inoculation experiments. For these reasons the following microbes seem to me most convenient for testing gaseous disinfectants :—

(1) Bacillus coli communis in young or old cultures, thick emulsions of the culture on agar being used to impregnate sterilised threads, fabrics, or porous paper.

(2) Bacillus pyocyaneus in young or old cultures, thick emulsions of the culture on agar being used as in No. 1.

(3) Staphylococcus pyogenes aureus in young or old cultures, thick emulsions of the culture on agar being used as in No. 1.

(4) Bacillus subtilis, sporing, in young or old cultures, thick emulsions of the culture on agar being used as in No. 1.

(5) Bacillus anthracis, sporing, in young or old cultures, thick emulsions of the culture on agar being used as in No. 1.

(6) Bacillus tuberculosis in sputum, fresh or dry, in capsules or spread on paper.

(7) Horse manure, with highly-resistant sporing bacilli, in young or old cultures, thick emulsions of the culture on agar being used as in No. 1.

I think a disinfectant capable of killing the six first organisms exposed to it in various states and under various conditions is, for practical purposes, a reliable disinfectant. If, in addition, it is capable of destroying the spores usually found in horse manure, and which often can resist for half an hour or more the action of saturated steam at 100° C., the disinfectant may be considered as exceedingly powerful.

The papers, fabrics, and threads infected with the test cultures were exposed either damp or dry to the action of the gas in the following ways :—

(*a*) In small glass capsules, loosely covered or uncovered.

(*b*) In narrow tubes $\frac{1}{4}$ inch wide and $2\frac{1}{2}$ inches long (fig. 3), closed at one end and sometimes plugged with cotton wool. These tubes were always placed in a horizontal position, or slightly inclined, so that their mouth should be turned downwards.

Fig 3

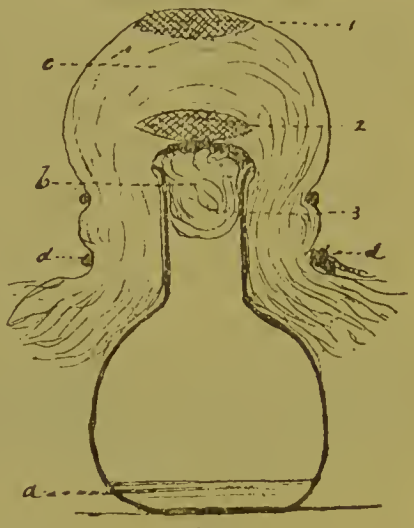

Fig 5

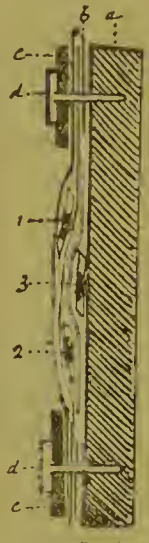

Fig 4

FIG. 3.—TUBE FOR TESTING THE ACTION OF GASEOUS DISINFECTANTS IN A DEEP RECESS WITH A NARROW OPENING.

a. Paper impregnated with the emulsion of the organism to be tested.
b. Loose cotton plug added in some of the experiments to increase the obstacles to the penetration of the gas.

(N.B.—*These tubes are usually laid horizontally.*)

FIG. 4.—ARRANGEMENT USED FOR TESTING THE POWER OF PENETRATION OF GASES THROUGH PAPER.

a. Wooden board.
b. Layers of paper, compressed by the ring (*c*).
c. Ring, firmly fixed to the board (*a*) by numerous fasteners.
d. Fasteners (nails with large head, or screws).
1. Test object under 1 layer of paper.
2. ,, ,, ,, 2 layers ,,
3. ,, ,, ,, 3 ,, ,,

FIG. 5.—FLASK CONTAINING DECOLORISED SOLUTION (B) OF FUCHSIN TO TEST THE PENETRATION POWERS OF FORMALDEHYDE.

a. Solution B.
b. Plug in mouth of flask. *c*. Thick covering of cotton wadding.
d. Twine tightly tied round cotton wool and neck of flask.
1, 2, 3. Parts tested for the presence of formaldehyde.

(*c*) Covered with one, two, or three layers of blotting-paper, fixed to a board in such a way as to prevent the access of the gas, except through the layers of paper (fig. 4). In part of the experiments envelopes of filter-paper were used.

(*d*) In some cases the test objects were kept damp all through the experiment by placing them over a dish of water, and as near the surface of the water as possible. Actual contact with water was sometimes allowed.

After removing the test objects from the disinfecting chamber they were left for several hours in a room free from formic aldehyde vapours, in order that the gas impregnating them should have an opportunity to diffuse out. The necessity of this step was indicated by the strong smell of formaldehyde which all porous objects, and even water, retained for several hours after being submitted to the action of the gas in the experimental room, and, by the slight change of colour produced in the media, and more especially in agar, to which bits of paper exposed to formaldehyde vapour had been added. The quantity of formaldehyde retained is not inconsiderable, as will be shown further on.

In some cases the test objects were also washed in a large amount of sterilised water.* Alkaline peptone bouillon and alkaline agar peptone bouillon were then inoculated with these objects, and the culture tubes examined daily for a week and afterwards at intervals during one month at least, in order to detect any evidence of growth. When there was any possible doubt as to the absence or presence of growth, gelatine plates were prepared with various quantities of the inoculated medium.

It is needless to say that in all cases control experiments were made with exactly the same material, mode of preparation, and conditions of keeping.

The Results Obtained may be summarised as on following pages.

The results obtained with the bacillus anthracis were somewhat remarkable in the seventeenth set of experiments; bacilli with young spores were found to resist an exposure which was fatal to much older spores.

The other failures were observed in No. XIII. set of experiments, in which spores 2 months old and kept dry for 5 months were unaffected by a 48 hours' exposure. In these cases the spores were protected from the access of the gas by one sheet of blotting-paper in the one and three sheets in the other; but the No. XVI. set of experiments shows that the gas can easily penetrate through three layers of filter-paper. It may be that in set No. XIII. the paper was a little damp, and opposed a more complete barrier to the passage of the gas. It is none the less satisfactory to find that in twelve cases out of nineteen anthrax spores were killed, under conditions which were often very unfavourable to the action of the gas.

Penetration Power (Diffusion) of Formaldehyde.—In order to obtain some definite data regarding the diffusibility of formic aldehyde gas, I made the following experiments. Two solutions were prepared capable of revealing minute quantities of formaldehyde:—

Solution A.—A 1 per cent. watery solution of fuchsin was decolorised by passing through it a current of sulphurous acid for forty-five minutes,

* Washing in dilute ammonia did not seem necessary considering the solubility of formaldehyde in water.

Nature of the Test Objects.	Number of experiment.	Number of burners.	Duration of exposure.	Quantity of spirit used.	Temperature of room.	Distance of object from lamp (approximate).	Height above floor.	Washing of objects after exposure.	Medium in which cultivated.	Growth.
I.—Bacillus Coli Communis.										
Culture on agar, 48 hours at 37° C.	1	6	24 hours	5,900 m.	20°	9 ft.	½ ft.	—	Bouillon	—
Filter-paper soaked in thick emulsion, dried thoroughly, and placed in envelopes of filter-paper.	2	,,	,,	,,	,,	11 ft.	6 ft.	—	Agar	—
	3	,,	,,	,,	,,	14 ft.	10½ ft.	—	Bouillon	—
	4	Control	...	...	...	...	...	—	Agar	Abundant
	5	,,	...	...	...	...	...	—	Bouillon	,,
II.—Bacillus Coli Communis.										
Culture on agar, kept 80 days at ordinary temperature, after being kept 48 hours in incubator at 37° C.	6	3	48 hours	4,500 m.	21·5°	7½ ft.	6 ft.	In water	Agar	—
	7	,,	,,	,,	,,	,,	...	Water used for washing	Bouillon	—
	8	,,	,,	,,	,,	12 ft.	10½ ft.	—	Agar	Rapid*
Impregnated paper placed in small tubes, and used before quite dry.	9	Control	...	...	...	...	...	Washed	,, bouillon	,,
	10	,,	...	...	...	...	...	Unwashed	Agar, bouillon	,,
III.—Bacillus Coli Communis.										
Culture on agar, 36 hours at 37° C.	11	3	24 hours	2,950 m.	22°	4 ft.	—	—	Agar	—
	12	,,	,,	,,	,,	,,	½ ft.	—	,,	—
	13	,,	,,	,,	,,	7½ ft.	6 ft.	—	Bouillon	—
Impregnated paper placed in small tubes, used before quite dry.	14	,,	,,	,,	,,	12 ft.	10½ ft.	—	Agar	—
	15	Control	...	...	...	...	...	—	Bouillon	Abundant
	16	,,	...	...	...	...	...	—	Agar	,,
IV.—Bacillus Pyocyaneus.										
Culture on agar, 48 hours at 37° C.	17	6	24 hours	5,900 m.	20°	4 ft.	½ ft.	—	Bouillon	—
Filter-paper impregnated with thick emulsion, thoroughly dried, and placed in envelopes of filter-paper.	18	—	—	—	—	7½ ft.	6 ft.	—	Agar	—
	19	—	—	—	—	12 ft.	10½ ft.	—	Bouillon	—
	20	Control	experiment		...	...	...	—	Agar	Abundant
	21	,,	,,		...	...	...	—	Bouillon	,,

Complete disinfection was obtained in each case.

* There was only one failure out of ten experiments. It is probable that in that case the tube in which the infected paper had been placed was too tightly plugged to allow the passage of the gas.

V.—Bacillus Tuberculosis.										Tuberculous lesions after thirty-seven days.
Tuberculous sputum expectorated on the day before the experiment. Thick drops deposited on paper 24 hours before the experiment and allowed to dry. The central parts of the drops were still soft and slightly moist when the papers were exposed to the gas. The infected papers were covered in each case either with one layer or two layers of filter-paper.	22	3	24 hours	2,950 m.	22°	9 ft.	½ ft.	Guinea-pig inoculated subcutaneously		—
	23	—	—	—	—	11 ft.	6 ft.	,,	,,	—
	24	—	—	—	—	14 ft.	10½ ft.	,,	,,	—
	25	Control	experiment		...	...	...	,,	,,	*Well marked*
	26	,,	,,		...	...	...	,,	,,	—
	27	,,	,,		...	...	...	,,	,,	—
	The comparatively large masses of sputum introduced under the skin produced in four cases out of six slight local induration, but no tubercle bacilli were found in the local lesion. In only one of the controls typical tuberculous lesions were produced, so that the sputum used was unfortunately not very virulent. With this reservation the experiments indicate complete disinfection of the sputum.									
VI.—Staphylococcus Pyogenes Aureus.										Growth.
Culture on agar, 48 hours at 37° C. Filter-paper impregnated with thick emulsion, thoroughly dried, and placed in envelopes of filter-paper.	28	6	24 hours	5,900 c.c.	20°	9 ft.	½ ft.	—	Bouillon	—
	29	,,	,,	,,	,,	11 ft.	6 ft.	—	Agar	—
	30	,,	,,	,,	,,	14 ft.	10½ ft.	—	Bouillon	—
	31	Control	experiment		...	...	...	...	Agar	Abundant
	32	,,	,,		...	...	...	...	Bouillon	,,
VII.—Staphylococcus Pyogenes Aureus.										
Culture on agar, kept for 72 days at ordinary temperature after being left for 48 hours in incubator at 37° C.	33	3	48 hours	4,500 m.	21·5°	11 ft.	6 ft.	Washed in water	Agar	—
	34	,,	,,	,,	,,	,,	,,	Water used for washing	Bouillon	—
	35	,,	,,	,,	,,	14 ft.	10½ ft.	—	,,	—
Impregnated papers placed in small tubes and exposed before being quite dry.	36	Control	experiment		...	...	...	Washed	Agar	Abundant
	,,							Unwashed	Bouillon	,,
	37	,,	,,		...	...	...	Washed	Agar	,,
	,,							Unwashed	Bouillon	,,

Nature of the Test Objects.	Number of experiment.	Number of burners.	Duration of exposure.	Quantity of spirit used.	Temperature of room.	Distance of object from lamp (approximate).	Height above floor.	Washing of objects after exposure.	Medium in which cultivated.	Growth.
VIII.—Staphylococcus Pyogenes Aureus. Culture on agar, 24 hours at 37° C. Impregnated paper placed in small tube and exposed when nearly dry. Except in experiment 41, in which the paper was kept in a small loosely-covered glass capsule and exposed (still covered) while still quite moist.	38	3	24 hours	2,950 m.	22°	9 ft.	½ ft.	—	Agar	None visible after 7 days; very slight growth at the end of 1 month*
	39	,,	,,	,,	,,	11 ft.	6 ft.	—	Bouillon	—
	40	,,	,,	,,	,,	14 ft.	10½ ft.	—	Agar	—
	41	,,	,,	,,	,,	10 ft.	...	—	,,	—? *
	42	Control	experiment		...	...	...	—	Bouillon	Abundant
	43	,,	,,		...	...	...	—	Agar	,,
IX.—Bacillus Subtilis. Spores not resisting the action of saturated steam at 100° for more than 2 minutes.	44	3	48 hours	4,500 m.	21·5°	11 ft.	6 ft.	Washed with water	,,	,, †
Filter-paper impregnated with thick emulsion of spores from a culture on agar 10 days old.	45	,,	,,	,,	,,	,,	,,	Water used for washing	Bouillon	—
Impregnated papers placed when quite dry in a small tube.	46	,,	,,	,,	,,	14 ft.	10½ ft.	—	,,	—
	47	Control	experiment		...	...	...	—	,,	Abundant

* One certain failure out of ten experiments. In experiment 41 there seemed to be a faint growth at the end of 1 month, but it was not possible to obtain any subculture, so that, if some cocci survived after the exposure, their growth was very limited and they rapidly died. In experiment 38 there was no evidence whatever of growth at the end of 1 week, and it was only towards the end of the month that an exceedingly scanty growth appeared.

† One failure, probably due to want of penetration of the gas through a thick layer of spores. The superficial spores had been killed, for none of those which became detached from the paper during the washing showed any sign of growth in the course of 1 month.

	48	3	48 hours	4,500 m.	21·5°	9 ft.	½ ft.	Washed with water	Agar	Growth doubtful up to 15th day; slight after 30 days*
X.—Sporing Aërobic Bacillus from Horse Manure.	49	,,	,,	,,	,,	,,	,,	Water used for washing	Bouillon	Growth slight after 5 days; abundant after 10 days
Resembling the bacillus subtilis, the spores were able to stand exposure to saturated steam at 100° for nearly half an hour.	50	,,	,,	,,	,,	11 ft.	6 ft.	—	,,	Growth slight on 2nd day; abundant on 5th day
Agar culture 1 week old..... Impregnated papers nearly dry placed in small tubes.	51	,,	,,	,,	—	14 ft.	10½ ft.	—	Agar	Growth doubtful on 30th day
	52	Control	experiment		...	...	...	—	Bouillon	Abundant on 2nd day
	53	,,	,,		...	...	...	—	Agar	,,
	54	3	48 hours	4,500 m.	21·5°	4 ft.	—	Washed in water	Agar	Abundant growth †
XI.—Dry Horse Manure. Containing spores of the organism used in set X. Small masses about ½ inch in diameter placed in tubes, when almost dry.	55	,,	,,	,,	,,	,,	—	Water used for washing	Bouillon	No growth till 15th day †
	56	,,	,,	,,	,,	,,	—	—	,,	Abundant growth †
	57	Control	experiment		...	...	...	—	,,	,,

* Three certain failures and one doubtful failure out of four experiments. The spores were distinctly affected by the gas. Their growth was inhibited for several days; in one case entirely stopped for 15 days.

† The formic aldehyde failed almost entirely to affect these highly-resisting spores in the midst of horse manure; all the other organisms present in the manure were apparently killed.

Nature of the Test Objects.	Number of experiment.	Number of burners.	Duration of exposure.	Quantity of spirit used.	Temperature of room.	Distance of object from lamp (approximate).	Height above floor.	Washing of objects after exposure.	Medium in which cultivated.	Growth.
XII.—Bacillus Anthracis.										
Agar culture 2 months old. Silk threads impregnated with thick emulsion of spores and kept dry in the dark for 18 months (two threads placed in each narrow tube).	58	6	24 hours	5,900 m.	20°	9 ft.	½ ft.	—	Bouillon	—
	59	,,	,,	,,	,,	11 ft.	6 ft.	—	Agar	—
	60	,,	,,	,,	,,	14 ft.	10½ ft.	—	Bouillon	—
	61	Control	experiment		...	...	...	—	Agar	Abundant
XIII.—Bacillus Anthracis.										
Agar culture 2 months old. Filter-paper impregnated with thick emulsion, dried and kept in dark cupboard for 5 months.	62	3	48 hours	4,500 m.	21·5°	11 ft.	6 ft.	Washed in water	Agar	Abundant
	63	,,	,,	,,	,,	,,	,,	Water used for washing	Bouillon	Doubtful
Experiment 62, test paper placed under one sheet of filter-paper; 64 under three sheets.	64	,,	,,	,,	,,	14 ft.	10½ ft.	—	Agar	Abundant
	65	Control	experiment		...	...	...	—	Bouillon	Moderate
XIV.—Bacillus Anthracis.	66	3	48 hours	4,500 m.	21·5°	11 ft.	6 ft.	Washed in water	Agar	—
Agar culture 12 months old. Filter-paper impregnated with thick emulsion, placed in narrow tubes, and kept for 18 hours in cold, *moist chamber*.	67	,,	,,	,,	,,	,,	,,	Water used for washing	Bouillon	—
	68	,,	,,	,,	,,	14 ft.	10½ ft.	—	,,	—
	69	Control	experiment		...	...	...	—	,,	Abundant
XV.—Bacillus Anthracis.										
Same culture as in XIV. Papers dried rapidly in hot chamber at 37° C. after being placed in tubes.	70	3	48 hours	4,500 m.	21·5°	9 ft.	...	—	Bouillon	—
	71	,,	,,	,,	,,	12 ft.	10½ ft.	—	,,	—
In experiment 70 dry tube kept during exposure over a dish of water.	72	Control	experiment		...	...	...	—	,,	Abundant

XVI. Bacillus Anthracis.										
Same culture and threads as in set XII.										
73. threads placed in small tube ...	73	3	24 hours	2,950 m.	22°	4 ft.	—	—	Bouillon	—
74. „ „ under one sheet of paper.	74	„	„	„	„	„	½ ft.	—	„	—
	75	„	„	„	„	7½ ft.	6 ft.	—	Agar	—
75. threads placed under two sheets of paper.	76	„	„	„	„	12 ft.	10½ ft.	—	Bouil lon	—
	77	Control	experime	nt		...	...	...	—	„ Moderate
76. threads placed under three sheets of paper.										
XVII.—Bacillus Anthracis.										
Agar culture 24 hours old. Filter-paper impregnated with thick emulsion. Placed in narrow tubes and kept for 6 hours, till nearly dry before exposure.	78	3	24 hours	2,950 m.	22°	9 ft.	½ ft.	—	Agar	Moderate
	79	„	„	„	„	11 ft.	6 ft.	—	Bouillon	„
	80	„	„	„	„	14 ft.	10½ ft.	—	Agar	Moderate, delayed
In 81 the paper was left in a covered capsule and kept moist all through the experiment.	81	„	„	„	„	4 ft.	...	—	„	„
	82	Control	experime	nt		...	...	...	—	„ Abundant

after which the bottle was tightly stoppered. In this way a solution containing a large excess of sulphurous acid was obtained. No trace of the colour of fuchsin remained after a few hours, and on exposing the fluid to the air in an open vessel a large amount of sulphurous acid was given off.

Solution B.—Twenty parts of a $\frac{1}{2}$ per cent. watery solution of fuchsin were mixed with ten parts of a decinormal solution of hyposulphite of soda, then dilute sulphuric acid was added gradually until all the red colour had disappeared. In such a solution there is such a slight excess of sulphurous acid that when freshly prepared it gives off practically no sulphurous acid. The slight precipitate of sulphur which is thrown down does not interfere with the reaction.

I devised this second preparation to obtain a more delicate reagent than the first, and one which did not give off a large quantity of gas.

I used the first solution in order to find whether the slow but constant generation of gas in a vessel with a narrow opening would interfere with the penetration of formaldehyde.

When a small quantity of formaldehyde is added to either solution a red colour appears which is of a more bluish tint than that of the original fuchsin. The tint and the intensity of the colour vary according to the proportion of formaldehyde.

A small quantity (about 3 c.c.) of solution A was poured into three small flasks, of a capacity of about 50 c.c., and with a mouth measuring from 1 c.m. ($\frac{3}{8}$ inch) to 1·5 c.m. (about $\frac{5}{8}$ inch) in diameter.

Three similar flasks were prepared with solution B.

Four of the flasks were loosely plugged with cotton wool; the other two were left freely open.

Another flask prepared in the same way with solution B, and, after being plugged, was enveloped in a thick layer (1 inch) of cotton wool, the cotton wool being tied tightly round the neck of the bottle (fig. 5). Some shallow capsules were half filled with the solutions. Other glass dishes were filled with pure water. Finally, into four narrow test tubes, measuring $\frac{3}{16}$ inch in diameter, and respectively 3, 6, 9, and 12 inches in length, a small quantity of solution B was poured.

These twenty vessels were placed in various parts of the disinfecting chamber, exactly in the same way as the papers, &c., impregnated with microbes, had been, *i.e.*, some were placed near the ceiling, others 6 feet above the floor, and others on the floor itself.

The lamp was loaded with 1,000 c.c. of methyl alcohol and lighted. The room was closed and reopened after eighteen hours.

It was then found that in all vessels, with the exception of three, a well-marked formaldehyde reaction had been produced. It was most intense in the opened capsules than in the opened and in the loosely-plugged flasks. It was least marked, in fact very slight, in the narrow

tubes measuring 6 inches in length. There was no trace of reaction in the 9 and 12-inch tubes. In the 3-inch tube the reaction was almost as intense as in the flasks (the tubes had been laid horizontally on the floor). The water in the glass dishes had a well-marked smell of formaldehyde, and gave with the two test solutions a reaction almost equal to that produced by a solution of formaldehyde of the strength of 1 in 1,000. No trace of acid reaction could be detected in it. There was no appreciable difference between the vessels left on the floor and those placed immediately under the ceiling.

The vapours had evidently not reached the fluid in the flask which had been wrapped up in cotton wool. In order to ascertain how far it had penetrated, a portion of the external layers of the wool was cut off and tested for the presence of formaldehyde; it gave a well-marked reaction. A second portion was taken from the deepest parts of the cotton-wool layer, just over the mouth of the flask (*i.e.*, 1 inch from the surface); this also gave a reaction almost equal to that given by the external layers. Finally the plug was removed from the neck of the flask, and this also gave the reaction, but more feebly. The gas had, therefore, penetrated through a layer of cotton wool at least $1\frac{1}{2}$ inch in thickness. The same cotton wool gave no reaction whatever when it had not been exposed to the gas. It must be remembered that in these experiments the quantity of methyl alcohol used was only one-third of that used in the disinfecting experiments.

Formaldehyde has, therefore, penetration powers probably greater than those of most other active gaseous disinfectants.

Summing up of the Results.

(1) With unimportant exceptions the *bacillus coli communis*, *bacillus pyocyaneus*, *bacillus tuberculosis*, *and staphylococcus pyogenes aureus were killed* whether in the dry or moist state, even when placed in deep, narrow recesses (2 inches from the opening of tubes open only at one end) or protected by one to three layers of filter-paper, or embedded in a thick layer of sputum.

(2) The *spores of the bacillus anthracis* were killed in twelve experiments out of nineteen, made under conditions not favourable to the free access of the gas. The differences in the results seem to have been due more to certain states of the spores than to variability in the action of formic aldehyde.

(3) The action on spores of the *bacillus subtilis* was uncertain. The very highly-resisting spores of a horse-manure bacillus, resembling the hay bacillus, could not be killed by exposures of a practical duration. The only evidence of action was a distinct delay in their growth.

Sulphurous acid, vapours of phenol, of cresol, of izal, dry chlorine, which have been all tried in my laboratory under the same experimental

conditions as those described above, have given to me results inferior to those obtained with formic aldehyde gas. The management of the lamp used in my experiments is very simple, and unattended with any inconvenience or danger.

The lamp itself is not expensive; but wood spirit of the proper quality and strength costs 10s. per gallon. As I have not determined the minimum quantity of spirit which would be sufficient for ordinary purposes I cannot estimate the exact cost of this method of disinfection. I am convinced, however, that formic aldehyde gas is a more efficient gaseous disinfectant than any of the others I have tried.

Its powers of diffusion are considerable, so that it can easily penetrate into recesses which offer serious barriers to most of the other gaseous disinfectants. The irregularities of action which I have observed are very slight when compared with those occurring with other disinfecting gases.

Fabrics made of various materials are quite unaffected by the gas, and very few colours are altered by it, and that to a slight extent only.

By taking the precaution of not remaining long in the room to be disinfected after the gas has begun to be generated, and by leaving the door open for ten minutes before entering the room again, it is easy to avoid the unpleasant irritation of the eyes and bronchial mucous membrane which formaldehyde produces when inhaled in even moderate quantities.

It is quite evident that formaldehyde is the best gaseous disinfectant we possess at the present time for objects which are liable to be damaged by damp, chlorine, dry and moist heat.

I do not give here an account of disinfection by formaldehyde, but only of a few experiments. Several papers have been published in this country in which information of a more general character will be found. I may, for instance, refer the reader to a contribution by Dr. Kenwood and Dr. Curtis in the *Journal of the Sanitary Institute*, January, 1898, Vol. XVIII, p. 406, in which bibliographical references are given. Also to Slater and Rideal (*Lancet*, April, 1894); Rideal: *Disinfection and Disinfectants*, London, 1895, p. 219.